AP® PHYSICS B
2009 SCORING GUIDELINES (Form B)

General Notes About 2009 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point and a student's solution contains the application of that equation to the problem, but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics Exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics Course Description*.

4. The scoring guidelines typically show numerical results using the value $g = 9.8\ \text{m/s}^2$, but use of $10\ \text{m/s}^2$ is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

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Question 1

15 points total **Distribution of points**

(a) 4 points

For any indication that the centripetal force on the small disk equals the weight of the hanging objects — 1 point

For using the correct expression for the centripetal acceleration — 1 point

$$\frac{m_1 v^2}{r} = m_2 g$$

For the correct expression for the speed of the disk in terms of the period — 1 point

$v = 2\pi r / P$

$$\frac{m_1}{r}\left(\frac{2\pi r}{P}\right)^2 = m_2 g$$

For a correct expression relating m_2 and P in terms of the specified quantities — 1 point

$$\frac{4\pi^2 m_1 r}{P^2} = m_2 g$$

$$P = 2\pi\sqrt{\frac{m_1 r}{m_2 g}}$$

(b) 2 points

For listing two quantities, one of which is correct, consistent with equation obtained in part (a) — 1 point

For having both quantities correct, consistent with equation obtained in part (a) — 1 point

For example: $1/P^2$ and m_2, P^2 and $1/m_2$, P and $1/\sqrt{m_2}$

(c) 4 points

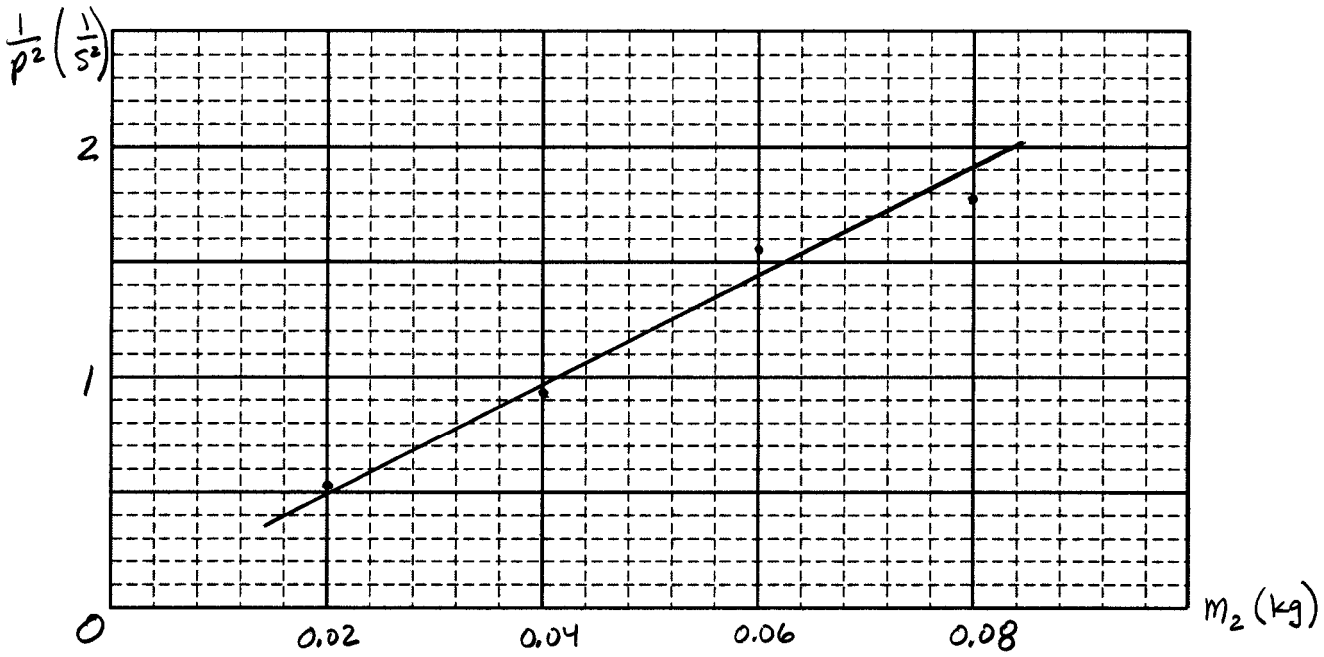
Using the example of $1/P^2$ and m_2

m_2 (kg)	0.020	0.040	0.060	0.080
P (s)	1.40	1.05	0.80	0.75
$1/P^2$	0.51	0.91	1.6	1.8

Question 1 (continued)

Distribution of points

(c) (continued)



For correctly labeling both axes 1 point
For correctly scaling both axes 1 point
For a reasonably correct plotting of the data 1 point
For a reasonably correct best-fit line 1 point

(d) 5 points

For associating the slope of the line with the correct coefficient for the quantities graphed 1 point

For the example graph given, $\frac{1}{P^2} = \frac{m_2 g}{4\pi^2 m_1 r}$, so slope $= \frac{g}{4\pi^2 m_1 r}$

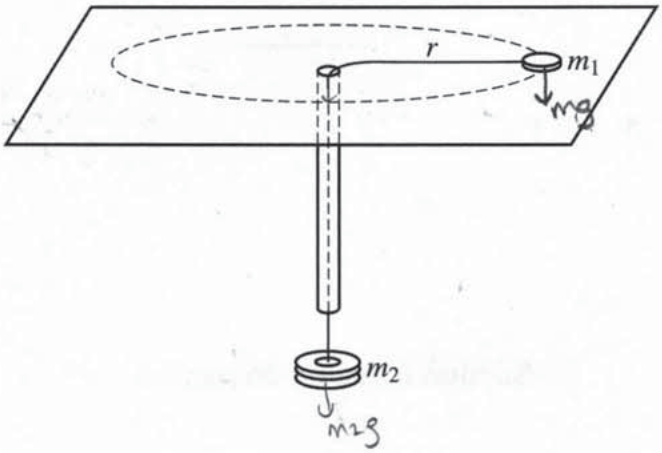
For a correct method of calculating the slope, including substitution of points on the line 1 point
For a correct substitution of given values (i.e., all values except the points from the line) 1 point
For example:

$$g = (\text{slope})\left(4\pi^2 m_1 r\right) = \frac{\left(2\ \text{s}^{-2} - 0.4\ \text{s}^{-2}\right)}{(0.084\ \text{kg} - 0.016\ \text{kg})}\left(4\pi^2\right)(0.012\ \text{kg})(0.80\ \text{m})$$

For a reasonable numerical value 1 point
For correct units 1 point
$g = 8.9\ \text{m/s}^2$

PHYSICS B
SECTION II
Time—90 minutes
6 Questions

Directions: Answer all six questions, which are weighted according to the points indicated. The suggested times are about 17 minutes for answering each of Questions 1-4 and about 11 minutes for answering each of Questions 5-6. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the lavender insert.



1. (15 points)

An experiment is performed using the apparatus above. A small disk of mass m_1 on a frictionless table is attached to one end of a string. The string passes through a hole in the table and an attached narrow, vertical plastic tube. An object of mass m_2 is hung at the other end of the string. A student holding the tube makes the disk rotate in a circle of constant radius r, while another student measures the period P.

(a) Derive the equation $P = 2\pi\sqrt{\frac{m_1 r}{m_2 g}}$ that relates P and m_2. $\Sigma F = 0$

$P = \frac{2\pi r}{v}$ $\quad F = ma \quad F = m_2 g$

$= \frac{v^2}{r}$

$m_2 g = \frac{m_1 v^2}{r}$

$v = \sqrt{\frac{m_2 g r}{m_1}}$

$\frac{2\pi r}{\sqrt{\frac{m_2 g r}{m_1}}} = \frac{2\pi r\sqrt{m_1}}{\sqrt{m_2 g \cdot r}} = 2\pi\sqrt{\frac{m_1 r^2}{m_2 g r}}$

$P = 2\pi\sqrt{\frac{m_1 \cdot r}{m_2 \cdot g}}$

GO ON TO THE NEXT PAGE.

The procedure is repeated, and the period P is determined for four different values of m_2, where $m_1 = 0.012$ kg and $r = 0.80$ m. The data, which are presented below, can be used to compute an experimental value for g.

m_2 (kg)	0.020	0.040	0.060	0.080
P (s)	1.40	1.05	0.80	0.75
$1/P^2$	0.510	0.907	1.563	1.778

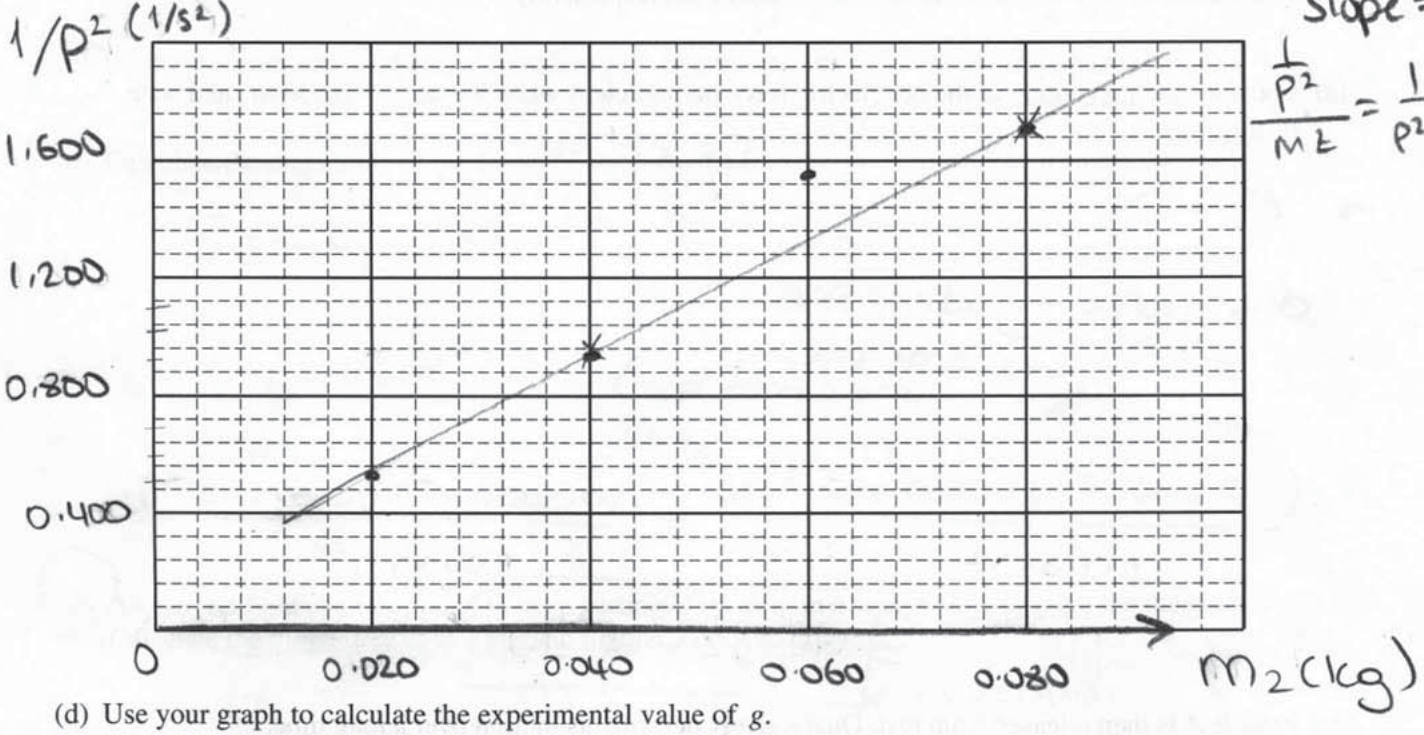
$g = 4\pi^2\left(\frac{M_1 \cdot r}{m_2 P^2}\right)$ ($4\pi^2$: constant; $M_1 \cdot r$: constant)

(b) What quantities should be graphed to yield a straight line with a slope that could be used to determine g?

$P = 2\pi\sqrt{\frac{m_1 r}{m_2 g}}$ $\quad \frac{P^2}{4\pi^2} = \frac{m_1 r}{m_2 g}$ $\quad P^2 m_2 g = 4\pi^2 m_1 r$

$\frac{1}{P^2}$ versus m_2

(c) On the grid below, plot the quantities determined in part (b), label the axes, and draw the best-fit line to the data. You may use the blank rows above to record any values you may need to calculate.



Slope = $\frac{\Delta \frac{1}{P^2}}{\Delta m_2} = \frac{1}{P^2 \cdot m_2}$

(d) Use your graph to calculate the experimental value of g.

$g = \frac{4\pi^2 \cdot m_1 \cdot r}{m_2 \cdot P^2} = \frac{4\pi^2 (0.012)(0.80)}{m_2 P^2 = (\text{slope})} = 8.252\ \text{m/s}^2$

$\text{slope} = \frac{\Delta 1/P^2}{\Delta m_2} = \frac{1}{P^2 \cdot m_2} = \frac{1.778 - 0.907}{0.080 - 0.040} = 21.775\ \text{s}^{-2}\text{kg}^{-1}$

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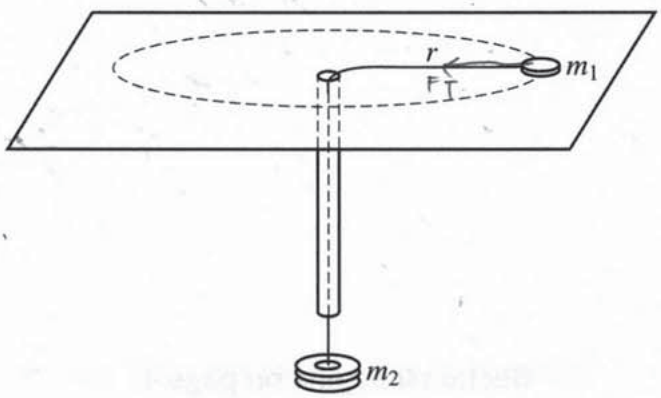


1. (15 points)

An experiment is performed using the apparatus above. A small disk of mass m_1 on a frictionless table is attached to one end of a string. The string passes through a hole in the table and an attached narrow, vertical plastic tube. An object of mass m_2 is hung at the other end of the string. A student holding the tube makes the disk rotate in a circle of constant radius r, while another student measures the period P.

(a) Derive the equation $P = 2\pi\sqrt{\frac{m_1 r}{m_2 g}}$ that relates P and m_2.

$F_T = m_2 g$.

$F_{T_1} = F_c = \frac{m v^2}{r}$.

$C = 2\pi r$.

$F_T = \frac{m_1 v^2}{r} = m_2 g$.

$t = \frac{d}{v}$

$\Rightarrow \frac{m_1 v^2}{m_2 g} = r$.

$\Rightarrow P = \frac{C}{v}$

$C = 2\pi\left(\frac{m_1 v^2}{m_2 g}\right)$

$P = \frac{2\pi\left(\frac{m_1 v^2}{m_2 g}\right)}{v} = 2\pi\sqrt{\frac{m_1 r}{m_2 g}}$

GO ON TO THE NEXT PAGE.

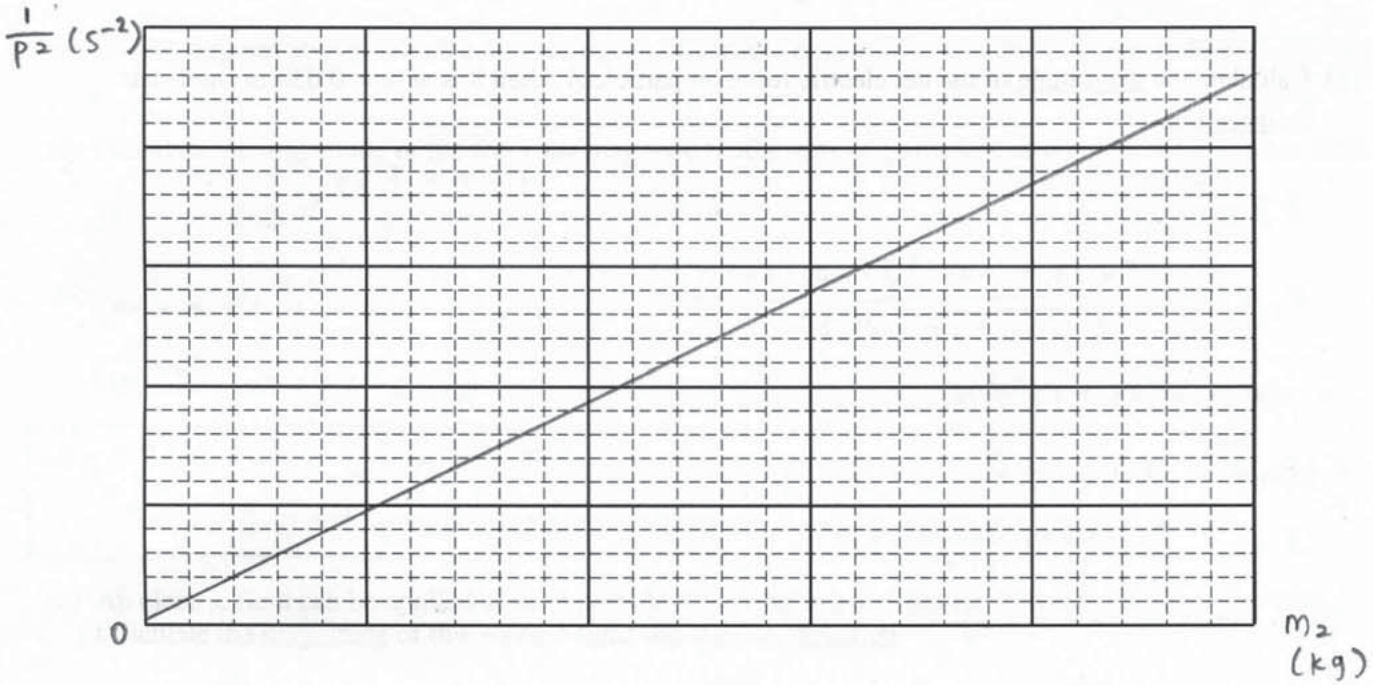
The procedure is repeated, and the period P is determined for four different values of m_2, where $m_1 = 0.012$ kg and $r = 0.80$ m. The data, which are presented below, can be used to compute an experimental value for g.

m_2 (kg)	0.020	0.040	0.060	0.080
P (s)	1.40	1.05	0.80	0.75
$1/P^2$	0.51	0.91	1.56	1.78

(b) What quantities should be graphed to yield a straight line with a slope that could be used to determine g?

$\frac{1}{P^2}$ and m_2

(c) On the grid below, plot the quantities determined in part (b), label the axes, and draw the best-fit line to the data. You may use the blank rows above to record any values you may need to calculate.



(d) Use your graph to calculate the experimental value of g.

$$g = \frac{m_1 r \times 4\pi^2}{P^2 \cdot m_2}$$

$$= 9.67 \text{ m/s}^2$$

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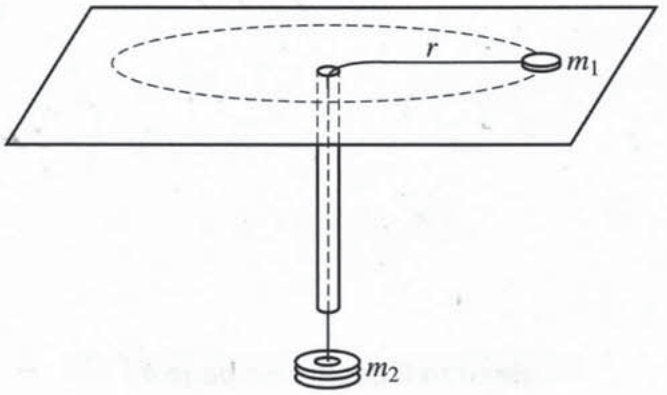
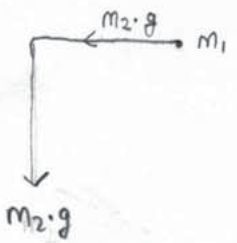
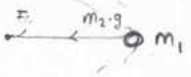


1. (15 points)

An experiment is performed using the apparatus above. A small disk of mass m_1 on a frictionless table is attached to one end of a string. The string passes through a hole in the table and an attached narrow, vertical plastic tube. An object of mass m_2 is hung at the other end of the string. A student holding the tube makes the disk rotate in a circle of constant radius r, while another student measures the period P.

(a) Derive the equation $P = 2\pi\sqrt{\frac{m_1 r}{m_2 g}}$ that relates P and m_2.





$F_c = m_2 \cdot g$

$m_1 \cdot \frac{(V_1)^2}{r} = m_2 \cdot g$

$(V_1)^2 = \frac{m_2 \cdot g \cdot r}{m_1}$

$P = \frac{\Delta x}{V_1}$

$= \frac{2\pi r}{V_1}$

$(V_1) = \frac{\sqrt{m_2 \cdot g}}{\sqrt{m_1}} \cdot \sqrt{r}$

$= \frac{2\pi r}{\frac{\sqrt{m_2 \cdot g} \cdot \sqrt{r}}{\sqrt{m_1}}}$

$= \frac{2\pi \sqrt{r} \cdot \sqrt{m_1}}{\sqrt{m_2 \cdot g} \cdot \sqrt{r}}$

$= \frac{2\pi \sqrt{r} \cdot \sqrt{m_1}}{\sqrt{m_2 \cdot g}} = 2\pi \frac{\sqrt{m_1 \cdot r}}{\sqrt{m_2 \cdot g}} = P$ //

GO ON TO THE NEXT PAGE.

The procedure is repeated, and the period P is determined for four different values of m_2, where $m_1 = 0.012$ kg and $r = 0.80$ m. The data, which are presented below, can be used to compute an experimental value for g.

m_2 (kg)	0.020	0.040	0.060	0.080
P (s)	1.40	1.05	0.80	0.75

$P = 2\pi\sqrt{\frac{m_1 r}{m_2 g}}$

$P^2 = 4\pi^2 \frac{m_1 r}{m_2 g}$

(b) What quantities should be graphed to yield a straight line with a slope that could be used to determine g?

P^2 and m_2 can be used

(c) On the grid below, plot the quantities determined in part (b), label the axes, and draw the best-fit line to the data. You may use the blank rows above to record any values you may need to calculate.

(d) Use your graph to calculate the experimental value of g.

GO ON TO THE NEXT PAGE.

AP® PHYSICS B
2009 SCORING COMMENTARY (Form B)

Question 1

Sample: B-1A
Score: 15

This response is an example of reasonably correct data plotting and best-fit line. The right-most data point in part (c) is a little off, and the line would have been better with a little more slope so it goes between some of the data points, but the work is acceptable. The use of "= (slope)" in the denominator of the first equation in part (d) might have been problematic if it was not clearly defined in part (c) and values were not substituted correctly.

Sample: B-1B
Score: 10

Part (a) earned all 4 points, and part (b) earned both points. Part (c) earned 1 point for labeling the axes. Part (d) earned only the 3 points for substituting the mass and radius, a reasonable answer, and correct units. Since there is no evidence that a slope is used and the answer is approximately the value obtained using the first data pair, the other 2 points were not earned.

Sample: B-1C
Score: 5

Part (a) earned all 4 points, and part (b) received 1 point for noting one correct quantity. The remaining parts received no points.